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FIRE BLIGHT
and its control

E. M. Hildebrand

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FIRE BLIGHT AND ITS CONTROL

E. M. Hildebrand

Fire blight, caused by *Erwinia amylovora,* is probably the earliest known bacterial disease of fruit trees in New York. Originally discovered in the highlands of the Hudson River Valley over a century and a half ago, it is now prevalent in fruit-growing districts throughout the United States, Canada, and New Zealand, and possibly is present also in Mexico. In the aggregate fire blight exacts a heavy annual toll. Its sporadic character and the suddenness with which it appears and ruins good orchards virtually overnight have given it the name *fire blight* and made it a disease apart from the ordinary.

Fire blight is largely the cause for the decline in pear growing in New York and for the gradual elimination of the more blight-susceptible varieties of apple and other plants. Judging by current practice New York growers have found it inexpedient to adopt the control measures now rather generally practiced in California,[1] owing in part at least to the small acreage of fruit trees on each farm and to the small yields that result from maintaining the trees in low vigor to escape fire blight.

Attempts to check the disease by growing susceptible trees in grass sod without adequate fertilization and without routine provision for disease control has not only resulted in unprofitable yields but has led to the neglect and loss of many orchards. Similar results have been obtained by fertilizing the trees without adequate disease control.

The problem confronting the grower then is one demanding that the trees be grown in a state of vigor conducive to good yields of fruit although this program at the same time intensifies the fire-blight hazard. The fact that fire blight is a difficult disease to handle should challenge rather than discourage the grower since the disease organism passes through several vulnerable stages at which effective control measures may be applied. Therefore, this bulletin emphasizes: (1) the importance to the fruit grower of becoming acquainted with the detailed story of the disease in order to know why certain control measures are recommended, and (2) the necessity of using control measures based upon prevention rather than cure of the disease.

[1]In California and in some of the other western districts where pear growing is still being well maintained, apparently satisfactory blight control by eradication is being achieved by the hiring of skilled operators to combat the disease. These men have learned how to do this work by diligent application to the problem in the field and are, for the most part, the better men chosen among orchard workers.

Fire blight attacks a large number of plants,[2] but this bulletin is chiefly concerned with the orchard fruits: pear, apple, and quince.

HOW TO RECOGNIZE THE DISEASE

THE NAME *fire blight* describes this disease rather well. The infected parts suddenly die and discolor, turning brown or black as though swept by a fire. Since all parts of the plant may be attacked, a number of names have evolved which describe the wide range of symptoms encountered — *blossom blight, spur blight, shoot blight, twig blight, sucker blight, terminal blight, branch blight, fruit blight, body blight, root blight,* and others. All are manifestations of the same disease. The symptoms usually appear in a certain order each year, starting at blossom time in the spring.

The diseased areas generally pass through certain characteristic stages of development regardless of the part of the tree involved. The bacteria that cause fire blight enter the plant through natural openings or through wounds and multiply rapidly, obtaining their food supply from the plant cells. The diseased tissue when examined from the outside shows first a water-soaked appearance, then a reddish color, and finally a brownish to black coloration. Usually, but not always, these changes are accompanied by the appearance of milky drops of ooze on the diseased surface which turn brown, dry, and persist for a long time in dry weather. These changes occur before the blossoms or leaves have had time to form abscission layers, which is why remnants of the blighted parts remain attached for months and even years where wind and rain have failed to whip them off. In extreme cases an entire tree may be killed or permanently crippled by this disease in a few months, a characteristic difference between fire blight and other fruit diseases.

STORY OF THE ORGANISM

THE LIFE story of the fire-blight organism through any one year, while complicated, is not hard to grasp when considered in relation to the season and to the stages in tree development. To the grower who is trying to practice an effective blight-control program, a knowledge of what may be happening to the bacteria at any particular time should be helpful.

[2]For a detailed list of plants susceptible to fire blight refer to *Fire Blight of Pears and Related Plants* by H. Earl Thomas and P. A. Ark. (Univ. California Agr. Exp. Sta., Bul. 586: 1–43. 1934.)

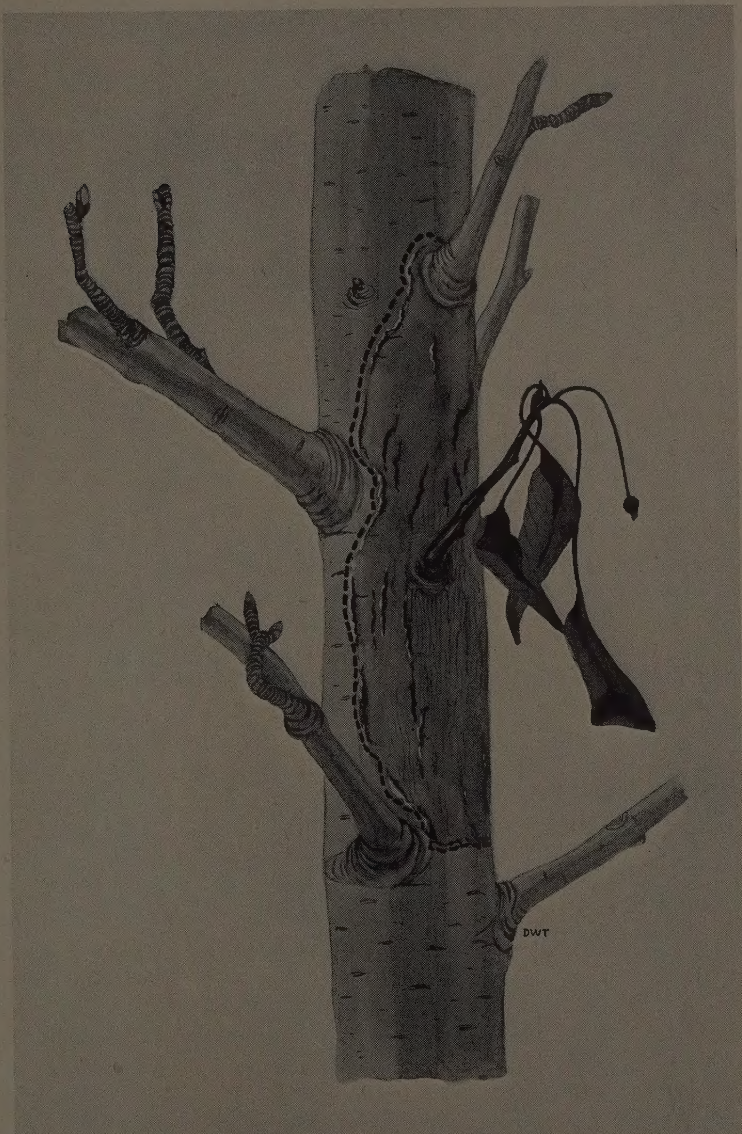


FIGURE 1. A DORMANT FIRE-BLIGHT CANKER ON PEAR IN NOVEMBER

The dotted line just outside the canker margin represents the approximate location of the bacteria during the dormant period

DORMANT PERIOD

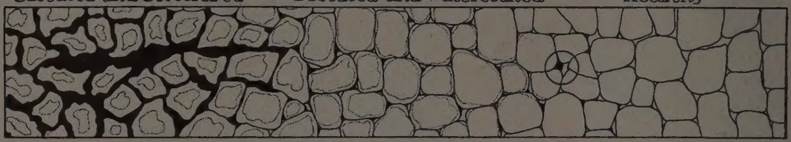


FIGURE 2. A NARROW STRIP OF CELLS WITHIN THE BARK AT RIGHT ANGLES TO THE CANKER MARGIN

The darkened spaces between the cells represent the location of the bacteria. The bark cells at the extreme right are healthy and those at the left are diseased

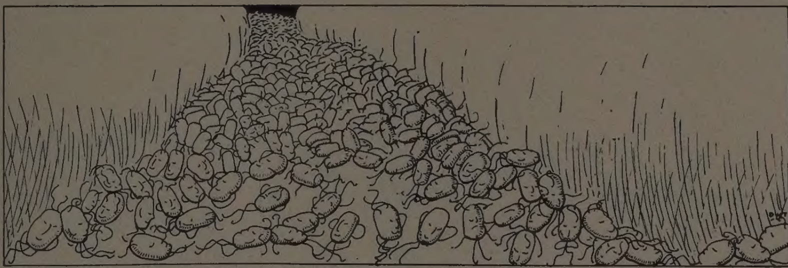
CANKERS that overwinter the fire-blight bacteria are on trunks, limbs, branches, and occasionally twigs of diseased trees during the dormant period, which extends from November to April. A dormant canker on pear during November is shown in figure 1. An almost continuous crack or crevice serves as the outer boundary of the canker.

Living bacteria are to be found principally in the normal-appearing bark at or just outside the canker margin in a narrow strip, never more than a fraction of an inch in width, separating dead from normal bark (see dotted line in figure 1). These dormant bacteria are embedded in a slimy secretion, or matrix, which when dry makes them better able to survive the winter. A narrow strip of tissue within the bark at right angles to the canker margin (figure 1) is illustrated in figure 2. The darkened spaces between the cells represent the location of the bacteria. The bark cells at the extreme left are diseased and dying and those at the extreme right are healthy. It is somewhere in the mid-region where survival usually takes place. An enlargement of one intercellular space, or cavity, is shown in figure 3. Here the bacteria are shown as light-colored, egg-shaped objects in a dark background which represents the slimy secretion in which the bacteria are immersed.

FIGURE 3. AN ENLARGEMENT OF ONE INTERCELLULAR SPACE OF FIGURE 2

The bacteria appear as colorless, egg-shaped objects immersed in a colored slime

This is without question the most vulnerable stage of the organism so far as control is concerned.

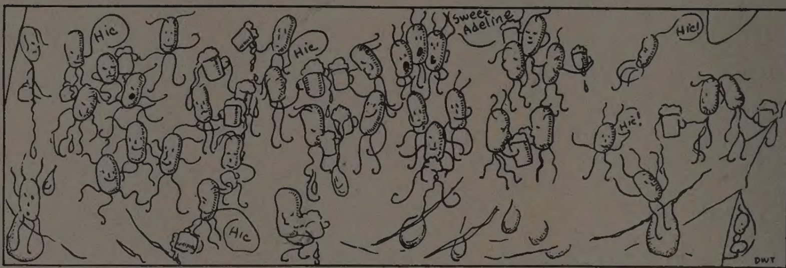

Frozen in sleep, perhaps the Blighter dreams of Spring

The bacteria are inactive in dormant cankers. If one were able to examine the cavities between the diseased plant cells at the canker margin during the dormant season, he would find numerous dormant bacteria. Low temperatures do not injure seriously the bacteria but only make them inactive. It puts them to "sleep". Should the temperature rise well above freezing for several days or longer in wintertime, the bacteria will become active again and cause the cankers to enlarge. This condition has been observed once in the past six years in New York.

After the fast of Winter they are ready for the feast of Spring

The tree breaks dormancy and the bacteria resume activity. The bacteria break dormancy at about the time sap flow starts in the trees in early spring. So far as the bacteria are concerned sap flow is the signal for the attack on the tree. The rising temperatures of early spring cause the sap to rise in the trees and at the same time to favor the development of the pathogenic bacteria which immediately attack the plant cells, killing them to obtain food.

EARLY BLOSSOM PERIOD

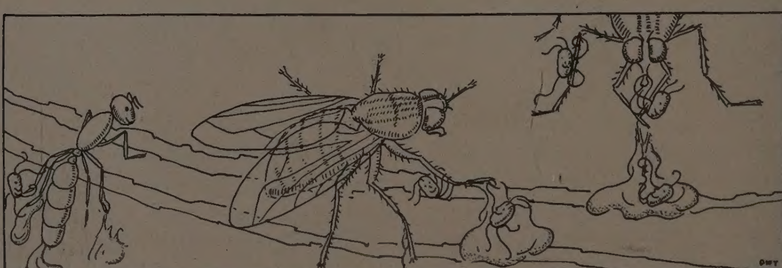


The Blighters indulge in an orgy of drinking

The bacteria multiply rapidly after sap flow begins. The first outward sign that the tree is breaking dormancy is the swelling of the fruit buds in anticipation of bloom. The tree sap by flooding the plant cells around which the bacteria are situated affords an excellent food source for bacterial growth and multiplication and for ooze production. As the bacteria multiply they spread to the adjoining areas of bark, causing the cankers to enlarge and further damage the trees.

Ooze production liberates the bacteria from the bark. Because of the excellence of growth conditions, the cavities between the diseased plant cells soon become gorged with the bacteria. The pressure of this growth forces droplets of the bacterial matrix to the surface of the diseased bark where they accumulate as milky beads of ooze. Ooze production, similar to that on hold-over cankers, is shown in figure 4. The occurrence of the ooze commonly coincides with the appearance of the earlier opening fruit blossoms.

BLOSSOM PERIOD



After the winter fast, anything looks good to flies and ants

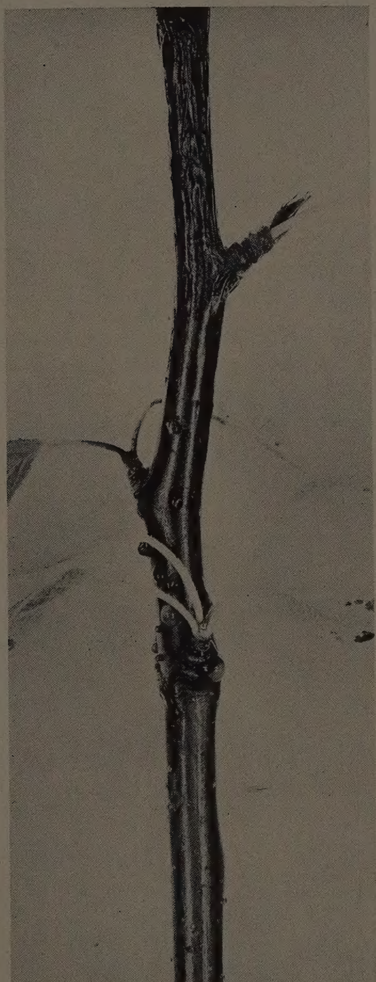


Figure 4. milky drops of bacterial ooze on the surface of a cankered branch, ready to be spread by insects or some other agency to healthy plants

The fly sometimes relishes a change in diet

EARLY spring insects feed on ooze. These insects consisting mostly of flies are attracted to and feed on the bacterial ooze, particularly when their food supply is low elsewhere. Since the ooze contains sugar in addition to bacteria and other substances, it is a real food. Several species of flies, ants, and other insects (aphids, beetles, moths, wasps, and others) are known to visit oozing cankers at different times during the growing season.

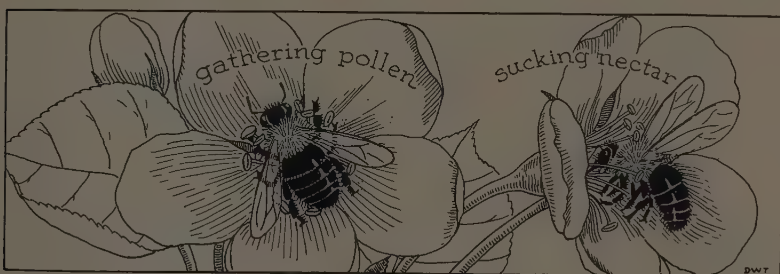
THE BACTERIA are carried to the fruit blossoms. Flies contaminated with the bacteria also visit fruit blossoms, thereby inoculating them with the bacteria. Thus the fly or other insect affords a natural means for the primary dissemination of the bacteria from overwintering cankers to the first new spring growth. The reason the insects shift their preference from the ooze of the cankers to the nectar in the blossoms is thought to be the difference in food value. For example, nectar has a much higher concentration of sugar than has the ooze. Incidental to this shift in taste on the part of the insects, the bacteria are transmitted to a new food supply also, where they may multiply and blight the plant.

The Blighters are washed - from one place to another

RAIN AND wind also disseminate the bacteria, and may function in the initial spread of bacteria from oozing cankers to fruit blossoms. The bacteria in the ooze may be splashed from the cankers to the blossoms within a radius of several feet, and a driving wind may blow contaminated rain to neighboring trees.

Whatever the method of transfer, this phase in the life history of the organism, in which the bacteria must pass from the overwintering cankers to the fruit blossoms, constitutes the second vulnerable stage where control measures may be employed to good advantage.

THE BACTERIA multiply in the blossoms. The bacteria carried to fruit blossoms by insects, rain, or wind may multiply there, (1) in the nectar, and (2) in the anthers which bear the pollen, before entering the blossom proper. Within one day's time a single bacterium may have multiplied to more than 100,000 bacteria, giving the nectar a milky appearance. Thus one such blossom has enough inoculum potentially to blight thousands of other blossoms, since a single bacterium is all that is needed to blight one flower. The fact that both nectar and pollen serve as reservoirs for these bacteria provides an ideal setting for the pollinating insects now entering the scene.



Both pollen and nectar are parts of bee diet

POLLINATING insects collect nectar and pollen. Honeybees and numerous other insects (bumblebees, solitary bees, flies, and others also) gather nectar and pollen in the spring and become contaminated with the fire-blight bacteria when visiting diseased blossoms. While only a very small proportion of the blossoms have become infected up to this time from overwintering sources through the action of flies and splashing rain, an occasional bee is sure to visit a diseased flower and become contaminated. Thus the conditions which favor the activities of pollinating insects likewise insure the secondary dissemination of the blight pathogen.

Insects carry the Blighters from diseased to healthy blossoms

THE POLLEN-gathering bee combs the pollen from the anthers, or pollen sacs, which are the uppermost organs in a blossom, and accumulates it in the so-called pollen baskets on its rear legs. Numerous pollen grains including those contaminated with the bacteria also become attached to the insect's body in the process and find easy access to the anthers or stigmas of flowers subsequently visited. The nectar-sucking bee likewise becomes contaminated when it pokes its proboscis, or sucking tube, into the nectary of an infected flower. It would be difficult, if not impossible, for a pollinating insect to visit an infected blossom without itself becoming contaminated.

The busy bee ranges far and free, and takes the Blighter with him

INSECTS spread the bacteria to other flowers. The busy insect moves from flower to flower until loaded and then returns to the hive leaving bacteria along the way. How long a contaminated insect may continue to inoculate blossoms is not known, but theoretically it could continue as long as two days or until all of the living pathogenic bacteria have been eliminated from its body. It should be mentioned here that although dry weather would ordinarily dry the nectar in pear blossoms and prevent infection

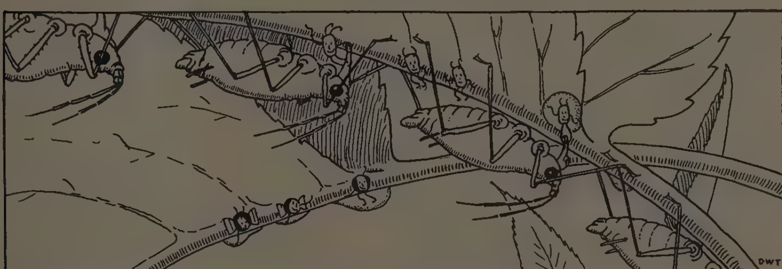
through the nectary, contaminated pollen coming to rest on the tip of the pistil or stigma may readily cause infection. The fact that pollinating insects are essential to the set of fruit complicates this phase of the fire-blight problem from the standpoint of control.

Wind and rain may also disseminate the bacteria. When weather conditions are favorable (about 60 per cent relative humidity), the bacterial ooze on blighting blossoms may occur in the form of minute threads or filaments (figure 5), instead of the more usual drops, and wind may break off and carry the fragments to neighboring trees. Splashing rain also may disseminate the bacteria from diseased to near-by healthy flowers. Under New York conditions, wind and rain are, however, of much less importance than are pollinating insects.

Figure 5. FIRE-BLIGHT OOZE IN THE FORM OF MINUTE FILAMENTS ON A PEAR FRUIT PEDICEL FOLLOWING BLOSSOM BLIGHT

This form of ooze may be carried by the wind. (Photograph from Dr. G. W. Keitt, University of Wisconsin)

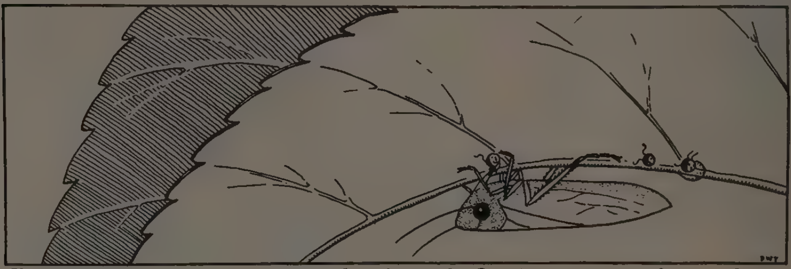
LATE SPRING AND SUMMER PERIOD



When aphids feed, the Blighters stick to them

The bacteria migrate into the young shoots. Among the first shoots to become infected in the spring are those arising from the fruit spurs. The bacteria may enter these shoots directly by way of the blighted spurs or through natural openings (breathing pores) after dissemination by splashing rain. This stage marks a new phase of the disease which lasts for the duration of shoot growth. Since blossom blight and shoot blight often

lead to canker formation at the base of spurs and shoots, especially in pears, active cankers, producing ooze, may be present almost continuously during the remainder of the growing season. Agents of dissemination such as rain, wind, insects, and man commonly are present also.



When the leaf-hopper punctures the plant the Blighter gets out for a ride

SUCKING insects feed on the succulent shoots. The most common method by which fire-blight bacteria spread from one shoot to another is by the regular migration of certain sucking insects that feed on the younger more succulent growth as the season advances. However, the bacteria may be disseminated also in a more limited way by other insects (ants, for example) and by rain and wind. The sucking insects that usually spread the bacteria are aphids, leafhoppers, and tarnished plant bugs. These insects may begin to appear soon after the first young shoots develop on the trees in the spring.

The leaf-hopper leaps to fresher feeding grounds, and carries a passenger

SUCKING insects carry the bacteria from infected to healthy shoots. In sucking the juices from the interior of infected shoots, these insects contaminate their mouth parts with the bacteria, and subsequent migration to healthy shoots starts new centers of inoculum. The bacteria are carried into the healthy tissue by the piercing mouth parts in much the same way

as they are introduced when puncturing with a needle.

This is a third period in the life of these bacteria which is vulnerable to control measures.

CANKER FORMATION

ALL THE invaded parts of highly susceptible trees may result in cankers. Canker formation at the base of a spur is shown in figure 6. Regardless of the court of entry, once within the bark the bacteria may migrate in all directions. After entry through spurs or shoots the bacteria may continue on into the second-year, third-year, and older growth, killing the bark all along the way. Ordinarily, however, the month of August marks a let-up in the disease activity, the margins of the cankers becoming more distinct because barriers of wound cork are formed in an attempt by the tree to head off or wall off the diseased from healthy bark. If no pronounced cork barrier is formed, the invasive powers of the bacteria are greatly retarded with the decline in the growth of the tree. Little advance

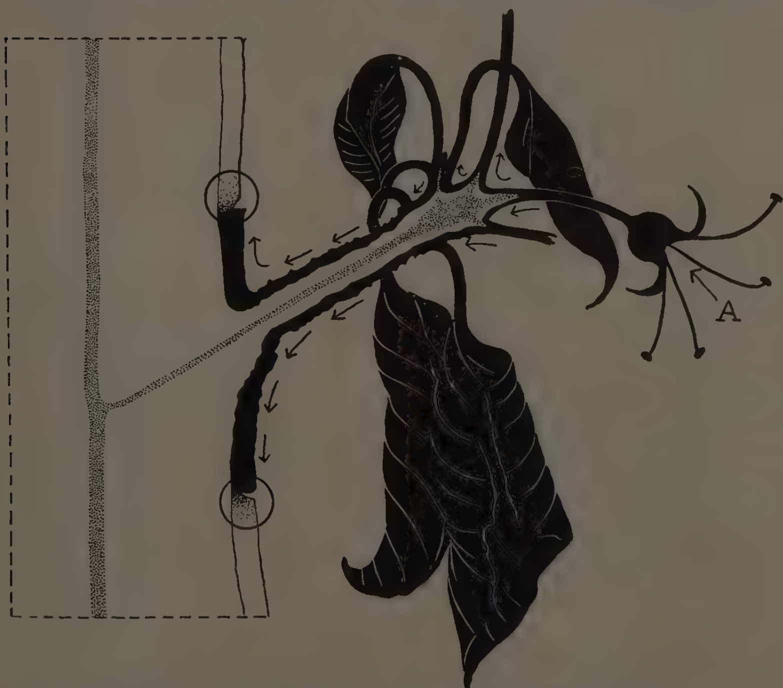


FIGURE 6. CANKER FORMATION AT THE BASE OF A FRUIT SPUR

The arrows indicate the path followed by the bacteria. The circles at the canker margins represent the approximate location of overwintering bacteria

may continue until the trees become dormant. It is known that the pathogen has continued to advance during warm periods in the winter at times when several days of above-freezing weather prevailed.

This completes the story of the fire-blight organism for one growing season back to the dormant period, the starting point.

CONTROL MEASURES

The chief deduction to be made from the story of the fire-blight organism is the seasonal character that control measures must assume. Generally, the control measures are directed at those stages in the development of the disease which are most vulnerable to attack; namely: (1) the dormant canker stage, (2) the blossom stage, and (3) post-blossom, or shoot, stage.

DORMANT PERIOD

The dormant season is the best time to eradicate cankers, for: (1) the cankers, as well as the trees, are quiescent and the danger of spreading the pathogen, even when no disinfectant is used, is small; (2) the cankers can be readily found, because there is no foliage to obscure them, and the canker margins, where the bacteria hibernate, are discernible as commonly there is a sharp break between dead and live bark; and (4) labor is more easily found for doing this work in winter than at other seasons.

Dormant cankers, black-rot cankers, and winter injury

Dormant cankers usually consist of dead patches of bark, reddish-brown in color. The surface of the blighted bark generally is smooth and even, except for the cracks or crevices that delimit the margins where the canker is joined to the healthy bark. The place where the bacteria entered usually is indicated on the surface of the canker by a blighted fruit spur, sucker, shoot, or wound made by an insect or tool. The very striking nature of fire-blight symptoms makes confusion with other diseases rather difficult. However, the time during the year when one is most likely to confuse fire blight with something else is during the dormant season. Under New York conditions the two troubles that are sometimes confused with fire-blight canker are black-rot canker and winter injury. Natural cracking of the bark, especially on pears, may also be confused with blight cankers.

Black-rot canker causes the bark to discolor first to a reddish-brown and later to almost black. The affected tissue sinks, thus forming a crevice where it joins the healthy bark. Some of these cankers die at this early stage, but in others the pathogen may spread and make a series of more or less concentric crevices, one for each year of development. The affected sunken bark remains in place for a year or more before cracking and falling

away, but before this happens small black fruiting bodies of the black-rot fungus appear on the dead bark. The appearance of these fungus fruit bodies and of the concentric rings with each year of canker growth are sure identifications of this disease, which is better known as a *fruit rot.*

Frequently the black-rot pathogen may invade dead or injured bark which may have resulted from fire blight, winter injury, or some other cause, and for this reason it is advisable to remove all dead or diseased bark to keep black-rot from gaining a foothold.

Winter injury, cold injury, and *frost injury* are names applied to a variety of symptoms resulting from excessively cold weather. This injury may be in the form of collar rot at the ground level, bark cracking and falling away from the main trunk, limb scald, and crotch injury.

Winter injury may be rather general, discoloring portions of the bark as well as the woody interior in varying degrees. When not too severe the bark may remain attached as though nothing had happened. As long as the cambium and the bulk of the sapwood are functioning, a certain amount of dead tissue can be tolerated and the tree may recover. Such injury may be readily distinguished from fire blight. The discoloration is not confined to the bark tissue as in fire blight but may be even more pronounced in the woody interior. Injured bark contains light-colored streaks, the tissue is watery, and pruning stubs exude or bleed. Severe winter injury in association with a fire-blight canker is shown in figure 7. While winter injury need not be confused with fire blight, it may kill the cambium and cause the bark to fall away from the woody cylinder and kill the tree.

FIGURE 7. SEVERE WINTER INJURY TO A CANKERED LIMB OF BARTLETT PEAR, WITH THE BARK CUT AWAY TO EXPOSE THE INTERIOR AT THE CANKER MARGIN

Winter injury (shown on the left) affects both the bark and the woody cylinder, causing them to turn black except for the typical light-color streaks in the bark. On the right is the characteristic reddish-brown blighted bark underlaid by apparently normal woody tissue

Kind of cankers to eradicate

Cankers on branches smaller than one-half inch in diameter usually do not carry the bacteria overwinter, but there is much variation in this respect between varieties and between seasons. Actually, the bacteria live through the winter in only a small percentage of cankers even on susceptible varieties. Since the fruit grower never knows which cankers will come through, all of those on the more susceptible varieties should be removed. Greatest emphasis must, of course, be placed on the removal of the cankers in the more important parts of the tree.

The surgical method of canker control

THE SURGICAL method of canker control is recommended for the dormant season because it is the oldest, most thoroughly tested, and probably the most effective method known. It requires skill and takes considerable time, but the hazard of spreading the pathogen in the winter is extremely small in comparison to that in the growing season.

Cankers may be eradicated: (1) by cutting off the diseased limbs entirely, known as the *excision method*, or (2) by cutting around the canker and scraping out the diseased bark, known as the *scraping method*.

The excision method

The excision method, while chiefly used on the smaller branches, is used also on the larger branches (comprising the scaffold or main framework of the tree) when the cankers extend more than one-half or two-thirds around the circumference. Excision cuts made during the dormant season should be at least four inches back from the visible canker margin in order to be sure that all tissue containing the bacteria has been removed.

The scraping method

The scraping method, recommended especially for cankers on the larger branches and the trunk, involves several steps: (1) a cut with a sharp knife about one inch outside and around the canker margin; (2) scraping away all the bark from inside the cut area; (3) protection of the wound from infection by treating it with a good disinfectant; and (4) exclusion of wood-rotting organisms by painting the surface with a wound dressing.

Scraping

The scraping method half completed on a small apple canker is shown in figure 8. It will be noted that the upper and lower tips of the wound have been pointed and that a minimum of bark has been exposed by holding the cutting tool at right angles to the branch, both of which precautions aid the healing of the wound. A special scraping tool (figure 9) facilitates

removing the cankered bark. It is evident also that in pointing the wound the cut is made farther away at top and bottom than at the sides.

After treatment of wounds

The after treatment of freshly made wounds while essential on the growing trees is considered a good precautionary measure in the dormant season. Little evidence shows that infection takes place while the trees are dormant, but during extremely mild weather cankers have been observed to advance. It would be nearly as difficult to locate the bacteria under such circumstances as in the summertime. Consequently, there would be the hazard of spreading the infection. Therefore, to be safe the recommendations must apply to the exceptional conditions even though there has been but one such winter in the past six years.

FIGURE 8. FIRE-BLIGHT CANKER HALF REMOVED ON A KING APPLE TREE
This illustrates the scraping method of canker control

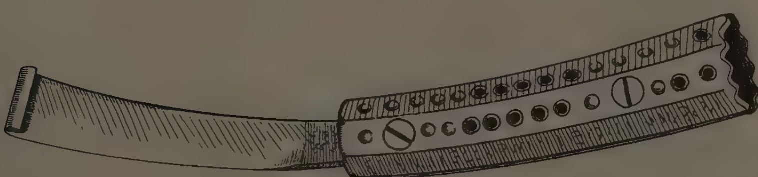


FIGURE 9. A BLACKSMITH'S HOOF-SHAVING TOOL USED FOR THE REMOVAL OF BARK IN THE SCRAPING METHOD OF CANKER CONTROL

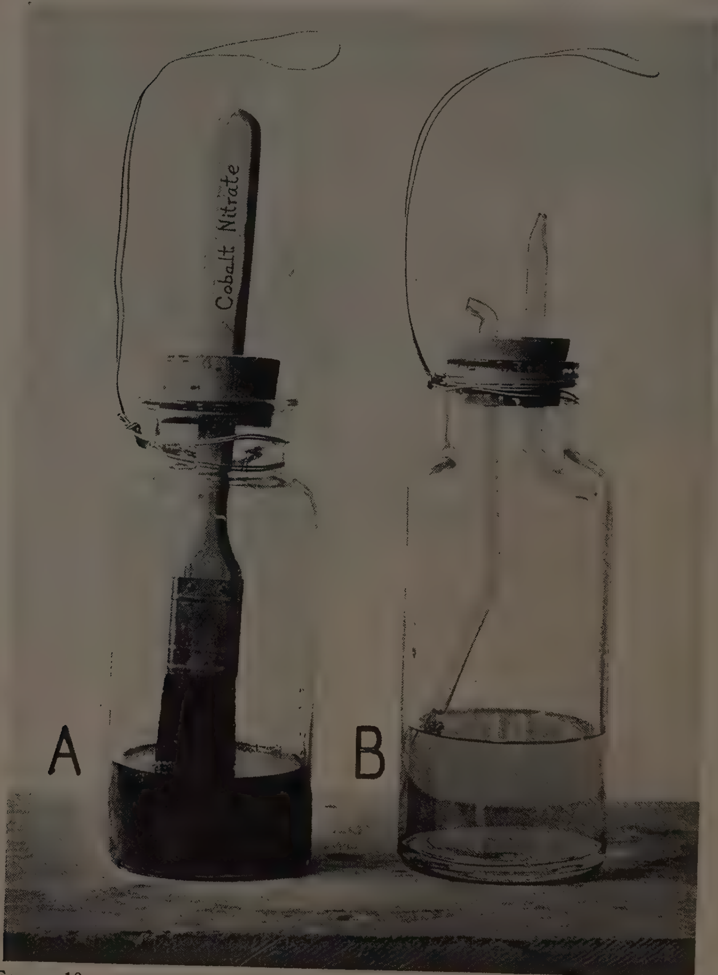


FIGURE 10. CONTAINERS FOR HANDLING DISINFECTANTS, WOUND DRESSINGS, AND CHEMICAL SOLUTIONS

A, A container, with brush handle passing through the cork, which is easy to make, convenient, and generally useful

B, A container, introduced by L. H. Day of California, which is especially suited for applying chemical solutions to the surface of cankers. The glass tube extending down in the bottle admits air while the solution is running out the upper tube

The disinfectant (figure 10A) should be applied immediately after the wound is made, in order to kill any organisms that may be present. The recommended disinfectant, Reimer's solution,[3] contains bichloride of mer-

[3]Reimer's solution is prepared on a weight basis by dissolving 1 part of bichloride of mercury and 1 part of cyanide of mercury in 500 parts of water. (California solution is identical except for the solvent which is made up of glycerine and water and usually in a 2 to 1 ratio.)

cury, which is an excellent disinfectant for tools, and cyanide of mercury, for the wounds. The disinfecting solution has only a temporary effect and therefore will not form a barrier to the entrance of wood-rotting organisms later in the season. For this purpose a wound dressing is required and should be applied without delay.

A good wound dressing should be non-injurious to the cambium, easy to apply, durable, and reasonable in cost. A fresh wound has a moist surface and therefore will not take one of the durable oil-base materials such as bordeaux-oil paint[4] until the surface is dry. When applied to a moist surface such materials will not adhere and will crack and fall away. To protect the wound, while in the process of drying, against the entrance of wood-rotting organisms, bordeaux-water paint is suggested.[5] This material, while not durable, will protect a wound for approximately one month, and by that time the wound will be ready for the more permanent material.

A water-asphalt-emulsion dressing is another alternative for use on fresh moist wounds after they have received the wound disinfectant. Water-asphalt emulsion, although non-toxic, adheres well to moist surfaces and forms a durable covering. It is sold under several trade names, but may be obtained in bulk, at a cost of about $1 a gallon, from most firms handling horticultural supplies. Many other wound dressings also are being sold. Each has its advantages and disadvantages. Any one would be better than no dressing at all, provided it was non-injurious to the cambium and would adhere well.

Prevention of body blight

Body blight which ordinarily results from bacterial entrances through blossom spurs and succulent shoots, such as suckers or water sprouts, may be prevented or greatly reduced by removing such growth before infection occurs. The healthy spurs may be broken or cut off during the dormant season any time before growth starts. The scaffold branches should be freed of spurs for a distance of several feet above the junction with the trunk, thus protecting the most critical part of the tree from invasion at blossom time. The effect of such removal on yields is negligible. Its chief advantage is that it limits the blossom infections to the smaller branches where control may be more easily effected than elsewhere.

[4]Bordeaux-oil paint is prepared by stirring powdered Bordeaux or copper-lime dust (20–80) into raw linseed oil until the mixture is of the consistency of a moderately thick paint. The receptacle should be of a non-corroding substance. Only enough material for one day's use should be made at a time.

[5]A number of wound dressings are on the market or one may be made up at home. Bordeaux-water paint is a good temporary wound dressing because it may be applied immediately to moist surfaces. It is prepared by adding powdered bordeaux or copper-lime dust (20–80) to water to form a fairly thick paint. Water asphalt emulsion is a good permanent wound dressing and may be applied directly to the moist freshly made wounds. The brands of materials used should not contain arsenicals.

BLOSSOM PERIOD

Blossom applications of sprays and dusts are made for the purpose of protecting the open flowers of fruit trees from invasion by the fire-blight organisms at a time when widespread dissemination is taking place chiefly through the activities of pollinating insects. To be effective, the bactericidal applications must be properly timed and must be thorough; that is, the bactericides must reach the flowers either before or at about the same time as the bacteria, and the sprays or dusts must cover completely the various parts of the flowers.

A full-bloom blossom treatment, when properly made, commonly reduces spur infections by one-half to two-thirds. This saves valuable fruit spurs that are needed to insure a commercial crop of fruit. The question is sometimes asked why a higher percentage of control is not readily attained. The probable reason is that a single application of a bactericide at full bloom usually will not protect more than 70 per cent of the flowers on a tree, as the remaining 30 per cent are already past bloom or are still unopened. At times the full-bloom treatment has given poor control, probably because of the time the bacteria first get into the blossoms. Should bacteria be introduced into an orchard very early in bloom, before the protective coating of bactericide is applied, it is evident that those flowers already invaded would not be protected. Because severe outbreaks of blossom blight are frequently associated with the introduction of the bacteria into the flowers early in the blossom period, the importance of making an additional early-bloom application is evident.

Materials

The two materials giving best control of blossom blight under New York conditions are bordeaux mixture 2–6–100, and copper-lime dust 20–80.[6] These materials have been tested over a period of six seasons in many orchards and in various parts of the State, and have proved superior to others tried. Encouraging results have been achieved also by several growers who have applied these materials to large acreages of blight-susceptible trees during full bloom.

Application of spray or dust

The number of applications advisable varies from season to season and from orchard to orchard. If blossom blight has been severe in the past, two applications are recommended — one at early bloom (when about one-fifth of the blossoms are open) and another at full bloom (when about three-fourths of the blossoms are open). Otherwise, a single application at full

[6]Other materials tested and giving promising results are copper phosphate and cuprous oxide.

bloom (when about 75 to 80 per cent of flowers are open) may be all that is necessary.

The spray (bordeaux mixture 2–6–100)[7] should be applied as a fine mist, preferably under good drying conditions. One method of preparing this mixture is as follows: Dissolve the copper sulfate in water (at the rate of 1 pound of crystals to a gallon of water) by suspending the crystals overnight in a porous cloth over a wooden or other non-corroding container. After filling the spray tank from one-half to two-thirds full with water, add 2 gallons of the stock copper-sulfate solution to the spray tank for each 100 gallons of spray volume desired. Next, add lime[8] (at the rate of 6 pounds to 100 gallons of spray mixture) to a suitable container and mix it with enough water to form a thin paste. Before mixing the chemicals in the tank start the agitator. The final step is to use a stream of water to wash the lime through a sieve into the tank until the tank is full.

Copper-lime dust (20–80)[9] should be applied, if possible, when the air is relatively still and the trees are wet with rain or dew. Otherwise the lime in the mixture quickly carbonates, leaving copper sulfate alone available which may cause injury when bordeaux would not. Early morning applications might prevent this possibility of injury.

Objections to the use of copper bactericides

OBJECTIONS are frequently raised to the use of bactericides at the blossoming period. It is argued that, since fire blight is sporadic in occurrence and cannot be predicted with certainty from season to season, the expenditure of labor and materials is often wasted. Other objections are the effect of bactericidal materials on pollen germination and the set of fruit, on pollinating insects, and on fruit and foliage.

Effect on the set of fruit

No effect on the set of fruit that could be considered of commercial concern has resulted from making one or more applications of bactericidal materials to the open flowers during the blossom period. Skipping the day the first flowers were beginning to open and then applying either the dilute bordeaux mixture (2–6–100) or copper-lime dust (20–80) daily for four days until petal fall, did not noticeably reduce the crop of McIntosh, Delicious, Rhode Island Greening, and Baldwin apples under good pollination conditions. Under poor pollination conditions serious blossom blight is rare in New York.

[7]The formula 2–6–100 means 2 pounds of copper sulfate and 6 pounds of lime (hydrated or stone) are mixed with water to form a volume of 100 gallons of spray.

[8]Either high calcium hydrated lime or stone lime is a good source of this material. A fresh supply each year is much to be preferred.

[9]The copper-lime dust if kept in tight containers and in a dry place may not seriously deteriorate (discolor) from one season to the next, but it is much safer to use a fresh supply.

Effect on pollinating insects

The effect on pollinating insects of applying bactericidal materials, such as sprays and dusts, to the open blossoms also appears to be of no practical importance. Observations made in the orchard and at an apiary about one-half mile away, have furnished no indication that copper bactericides produce any injurious effect on honeybees. Although these spray and dust materials have repelled bees in the laboratory, this has not been apparent in the orchard; the numbers of insects visiting sprayed and unsprayed trees were approximately equal. The reduction in the set of fruit was almost negligible on treated trees when conditions in the orchard were favorable for pollination.

Injury to fruit and foliage

That fruit and foliage injury may result from the use of copper-containing bactericides has long been known. The most perplexing problem is the sporadic occurrence of the injury. With care and attention in the application of the materials, injury seems to be less important. The fact that there has been only occasional superficial netting of apple and pear fruit in field experiments conducted by the writer during the past six seasons seems to indicate that such injury is less likely to occur in the bloom stage than at other periods. Moreover, the pink and calyx stages of fruit development seem to be more susceptible to injury than does the open-flower stage.

The place of copper bactericides in the orchard program

THE FRUIT grower faces the problem of deciding whether to use protective measures which will save a majority of the fruit spurs at the possible expense of some fruit russet and foliage injury, or to risk the consequences of fire-blight injury which he may attempt to alleviate by eradication.

Bactericides at blossom time are especially recommended for apple varieties such as Rhode Island Greening, Twenty Ounce, McIntosh, Baldwin, and others that are highly susceptible to blossom blight but otherwise are resistant to fire blight. The application of these bactericides to pears (all varieties) and to the highly susceptible varieties of apples (King, Spitzenberg, Transcendant Crab, Alexander, and others) is of much value because they also reduce the initial infections, the chief development of which is at blossom time.

Under certain conditions it is possible for the blossom bactericide to replace the pre-blossom application, when the need for a fungicide may be delayed a few days and an insecticide is not required. Moreover, it sometimes happens, more frequently in some places than in others, that apple-scab infections appear during bloom. The fungicidal property of the bactericides is an aid in combating such outbreaks.

POST-BLOSSOM PERIOD

Eradication of early infections following bloom

From ten to fourteen days after the blossom bactericides have been applied the pear trees and the more susceptible apple trees should be inspected for new infections. All infected fruit spurs and shoots should be broken out at once and destroyed. Also, at this time, the location of trees with blossom infections frequently enables the operator to find the cankers which served as sources of inoculum. These should be removed and the cuts disinfected. Subsequently for several weeks, at intervals of a few days, further inspections should be made and new infections removed as soon as possible after they appear. This prevents, as much as possible, the secondary spread of infections in the terminal growth.

Removal of sucker or water-sprout growth during summer

The succulent shoots, known as *suckers or water-sprouts,* which develop from the roots, trunk, and scaffold branches in the summer are ideal places for the bacteria to enter the trees and to produce cankers when inoculated by sucking insects. Therefore, it is important to remove this highly susceptible growth from the critical locations before infection takes place. With a pair of leather gloves these shoots may be rubbed off easily before they become woody. This practice, which supplements that of removing fruit spurs from the same locations, also helps to keep the centers of the trees open so that sprays may be applied more effectively.

Summer treatments in canker control

Despite the best efforts of fruit growers, some cankers ordinarily will appear during the growing season. These commonly are associated with infection courts such as fruit spurs and succulent shoots, and their control presents many difficulties. Unless the proper precautions are taken, more injury than benefit may result.

The summer surgical treatments for canker control require more judgment, skill, and time on the part of the operator than do similar treatments during the winter. Because the cankers are active, their exact margins are difficult, if not impossible, to locate. Except for this difficulty and the fact that summer treatments require sterilization of the tools between cuts, the same procedure is used for eradicating cankers in summer as in winter.

Surgical control

Excision

Excision cuts on the branches should be made well below the visible discoloration for distances ranging from one to two feet or more. Immediately after making the cuts, a disinfectant (Reimer's solution) should be applied. After this, a wound dressing such as bordeaux-water paint

(page 21) should be applied, especially to the wounds made by the excision of branches larger than one inch in diameter. Later on, a more permanent dressing should be applied to the larger cuts. Should any infection occur at wounds receiving this treatment it is almost certain that they resulted from failure to cut back far enough to remove all of the infection. Judgment on how to properly make such cuts can only be acquired by experience. More operators err in making the cuts too short rather than too long.

Scraping

THE SCRAPING method is used to advantage in the control of cankers on the scaffold limbs or branches and on the trunk where it is a question of saving these critical parts of the trees from destruction.

In the scraping method (page 18), the idea is to remove all the diseased tissue and to disinfect and dress the wound to prevent further infection. However, during the summer not only the discolored bark but often much of the apparently healthy tissue may contain the bacteria and be in an early stage of infection. There is no easy way to tell just how much or how little is involved. Manifestly the most important consideration is to locate and remove such tissue at the earliest possible moment before the cankers have gained much headway. Much more judgment and experience are required in using this method than in the excision method. Because of these inherent difficulties in the scraping method, attempts have been made to develop other summer treatments of which the application of penetrating chemicals to the bark surface is most important.

Chemical paints

THE PAINTING of penetrating chemical solutions over the surface of young active cankers is a rapid control method that eliminates the cutting operation and the accompanying hazard of spreading the infection. However, it requires a certain degree of skill to locate the approximate margins of the cankers and to handle the chemicals so as to prevent the solution from dripping or spilling on the fruit or foliage of the tree.

Chemical paints would seem to have a place in the orchard program, particularly in the early stages of canker development when checking the canker advance is so important to the future value of the tree. Stopping cankers at an early stage when the tree is actively growing, results in rapid recovery in the form of callus production with resultant early sluffing away of the dead bark.

Chemical paints also have their disadvantages. In the first place one-hundred-per-cent control is rarely achieved. Also, bark injury sometimes results. The writer is of the opinion that to control fire blight there must be a certain amount of chemical injury since it is extremely doubtful whether

a chemical solution will ever be found that will be toxic to the bacteria and not to the host tissues. Because chemical injury is never so great as is the blight injury if treatment is omitted, it would appear that chemicals should have a place in control recommendations.

Selection and preparation of chemical solutions

The three chemical paints that have been tested over a period of years under New York conditions are: (1) zinc-chloride solution; (2) cadmium-sulfate solution; and (3) cobalt-nitrate solution. So far there has been little difference in control between these three solutions, but from the tree-injury standpoint there has been considerable variation.

Zinc-chloride solution. Zinc-chloride solution[10] is the most injurious of the three solutions tested by the writer in New York, and produces from moderate to severe injury to apple and pear bark. This injury might considerably be reduced by using weak-

FIGURE 11. A BLIGHT CANKER ON BARTLETT PEAR CONTROLLED BY THE USE OF 43-PER-CENT ZINC-CHLORIDE SOLUTION

Only slight injury to the surrounding healthy bark is apparent from the use of the chemicals

[10]Zinc-chloride canker paint (43 per cent strength, according to the formula of L. H. Day of California).

Formula

Solvent	Denatured ethyl alcohol	1.0 quart
	Water (soft or distilled)	¼ pint
	Hydrochloric acid (commercial)	¾ ounce
	Zinc chloride	1½ pounds

Preparation

Dissolve the zinc chloride in the solvent. In dissolving, the solution becomes very hot. Stir the hot solution well with a wooden paddle and break up all the lumps until all the zinc chloride is dissolved. Avoid inhaling the fumes. Cool the solution as rapidly as possible, covering with a lid to prevent evaporation. Add a few drops of laundry bluing or other dye to give it color. Store it in well-corked bottles and it will keep a long time.

er strengths of the solution on the smaller, younger branches, which is the custom in California where this treatment originated. At its worst the injury (figure 11) is confined to only a fraction of an inch at the margin of the cankered area, which in most cases would be less objectionable than the blight injury in untreated cankers. This paint, more commonly used than the others, also produces injury to the healthy bark at the lenticels. If care is taken in its application to overlap the material and to prevent spilling it and letting it run down the bark, this type of injury should not prove extremely serious. However, it is because of this injurious tendency that zinc-chloride solution is not being generally recommended.

Cadmium-sulfate solution. Cadmium-sulfate solution[11] produces slight to moderate injury to pear and apple bark when applied during the summer. The injury when present is largely confined to the apparently healthy tissue at the canker margins.

Cobalt-nitrate solution. Cobalt-nitrate solution[12] is the newest of the three chemicals under consideration, and in New York causes by far the least injury. Since it produces only slight injury at most and at the same time gives approximately as good canker control as does either of the other treatments, cobalt-nitrate solution deserves wider trial by growers.

The chief place of the chemicals in the control program would seem to be in fighting the cankers on the larger limbs and the trunk which are handled with so much difficulty by the scraping method.

Selection and preparation of cankers for treatment

When working with chemical solutions certain precautions or preliminaries in the selection and preparation of cankers are advisable. In general, treatments should be attempted only when the cankers do not extend more

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[11] Cadmium-sulfate canker treatment (according to the formula of K. G. Parker).

The stock solution is made up at the rate of 1 part by weight of cadmium sulfate salt to 2 parts of distilled or rainwater. The salt is added to warmed water to accelerate the dissolving action.

Formula

Cadmium-sulfate stock solution	5 parts by volume
Hydrochloric acid (commercial)	2 parts by volume
Glycerine (commercial)	2 parts by volume
Denatured ethyl alcohol	5 parts by volume

Preparation

Add the acid to the cadmium-sulfate solution. Then add the glycerine followed by the alcohol, stirring constantly. Add a few drops of bluing or some other dye. Store the solution in a well-stoppered non-corrosive container and it will keep indefinitely.

[12] Cobalt-nitrate canker treatment (according to the formula of H. E. Thomas).

Formula (1 quart of solution)

Cobalt nitrate	100.0 grams (3½ oz.)
Glycerine (commercial)	50.0 cc. (1.7 fluid oz.)
Oil of wintergreen	100.0 cc. (3.4 fluid oz.)
Acetic acid	50.0 cc. (1.7 fluid oz.)
Ethyl alcohol (or denatured)	800.0 cc. (27.2 fluid oz.)

Preparation

Pour the fluids together while stirring. Add the cobalt nitrate salt and stir until dissolved. Store in tightly stoppered bottles.

than one-half the distance around the limbs, for the very obvious reason that limbs more than one-half girdled probably are not worth saving.

Trees to receive chemical treatment should be marked with a strip of cloth or some other conspicuous sign so they may be easily identified afterward. In order to have a basis later for telling whether the canker has ceased movement or not, two nails should be driven in at the canker extremeties.[13] It is sometimes advisable also to keep a brief record of the treatment. Failure to use these precautions makes it difficult to keep track of the results. This would not be important if the use of chemicals were not in the experimental stage.

It has been found by experience that chemicals will not satisfactorily penetrate rough bark. The outer corky layers should, therefore, be scraped away before one attempts treatment.

Method of applying chemical solutions

The surface, or "drenching", method of applying penetrating chemical solutions is based on the idea of disinfection, or killing the organism in the infected tissues, without too much injury to the plant.

The chemical solutions should be kept in glass, earthenware, or other non-corroding containers. Two convenient types of containers are shown in figure 10. By tilting the wash bottle (figure 10,B) the chemical solution flows out and may be spread over the canker surface with a brush. Another type of container has a brush with the handle passing up through the cork (figure 10,A). A pint fruit jar with metal clamp also makes a good container.

The chemical solution should be so applied that it will cover not only the canker surface, including the spur, sucker, or other infection court, but also the surrounding apparently healthy bark for several inches in all directions, in order to head off the invasion of bacteria.

If an ideal solution were available, this method has certain outstanding advantages. Even with materials at the present level of perfection, there seems to be a place for them.

The numerous small cankers which accompany a severe outbreak of fire blight present the strongest case for the use of chemicals in place of the scraping method. The chemical method saves time, saves bark, and eliminates the hazards of spreading the infection.

Checking results, and retreatment

From two weeks to a month after treatment the results should be checked and retreatments made where needed. At this time the importance of labeling the trees and of driving nails at the extremities of the cankers is

[13]It has been stated (page 25) that the canker margins in active cankers are difficult to determine. However, if the cankers are treated in an early stage of development as recommended, this difficulty is less of a problem.

evident. A canker not stopped by the first treatment should be painted again. In the writer's experience the only cankers requiring more than two treatments were those on large trees having rough bark not removed before treatment.

Acetylene torch

THE ACETYLENE-torch method of canker control has been tested as another alternative to the scraping method. It is not so well adapted to cankers that are in a rapid state of advance as are chemicals. Its chief place, if it should have any at present, is early in the season when the bacteria are just beginning to move into the tissue from the infection court or later in the season when the margins of the cankers are becoming delimited from the healthy tissue by a crack or crevice.

The principle of the treatment is to heat the surface of the bark and to bring the interior temperatures above the death point of the bacteria but not above that of the interior bark cells. The length of time to keep the flame at one point varies from approximately one second on a one-inch branch to about six seconds on a four-inch branch. The width of the flame can be varied by using different sized nozzles. In moving the flame around the canker margin, the heat not only inactivates the bacteria but has a tendency to stimulate the formation of a cork barrier because of its drying action.

ORCHARD PRACTICES AND FIRE-BLIGHT CONTROL

Because the severity of fire blight is related to the growth condition of a tree and because low vigor is associated with resistance to fire blight, many growers omit fertilization, pruning, and cultivation when the disease threatens. Ordinarily, blight damage is bad before such adjustments are made, and this has influenced some growers at least to maintain their trees on sod in a low state of vigor.

A level of vigor that will produce good yields of fruit is recognized as essential to realizing any profit from fruit growing.

Evidence gathered during the past few seasons indicates that young apple and pear trees grown under alfalfa culture suffer less from fire-blight injury than do those grown on either grass sod fertilized with nitrogen or those on cultivated soil with or without nitrogen fertilization. Under alfalfa culture there was also a more desirable lateral type of tree development, which is much to be preferred to the more upright character of growth which is so prevalent with grass sod plus nitrogen culture.

Attention should be given also to the fire-blight hazard when trees are fertilized, pruned, or ringed. The use of a complete fertilizer, even though no immediate outwardly visible benefits are apparent, deserves a trial in

comparison with the use of nitrogen alone. This practice is already recommended in New Jersey. Furthermore, the value of a quickly available nitrogen fertilizer, which has sometimes been recommended, seems to be questioned on the superiority of alfalfa over grass sod plus nitrogen.

Fertilizing with nitrogenous fertilizers, pruning, and ringing increase blight susceptibility by inducing greater succulency in the trees. Any of these practices should be undertaken with moderation. Since having the trees in good vigor is so important in obtaining yields, the fruit grower must face the situation realistically and work toward combining cultural practices with control practices that are adequate for the problem at hand.

DISEASE RESISTANCE

Blight-resistant pears of good quality are a recognized need of New York agriculture. Breeding pears for blight resistance, while underway in this State, is a slow and laborious job; so slow, in fact, that adequate support for the work is not readily obtained because satisfactory results cannot be predicted in the lifetime of the present generation of workers.

When making new plantings, the more blight-resistant varieties should receive preference. Also, plantings of blight-susceptible apples, pears, and quinces should be isolated from one another whenever possible to reduce the disease hazard.

SUMMARY OF THE BLIGHT-CONTROL PROGRAM

The New York fruit grower should follow with moderation the safest orchard practices from the standpoint of blight susceptibility that will keep the trees in good vigor and produce good yields.

No one measure can be recommended for the control of fire blight. Instead a number of seasonal jobs are required.

Dormant period

Eradicate from susceptible trees the cankers that overwinter the bacteria. Use surgical methods. When using the excision method, cut back into the healthy bark about four inches from the canker margin. The scraping method may be used when the canker does not extend more than one-half the distance around the circumference, in an attempt to save the branch in question. Disinfect the wounds. Apply a wound dressing.

Eradicate fruit spurs from the large scaffold branches.

Blossom period

Protect the open flowers on susceptible trees with a spray (bordeaux mixture 2–6–100) or a dust (copper-lime dust 20–80) applied once or twice during the blossom period. If blossom blight has been severe in the

past, make two applications of spray or dust: the first in early bloom (when about one-fifth of the blossoms are open) and the second at full bloom (when about three-fourths of the blossoms are open). Otherwise make one application at full bloom. The likelihood of blossom infection should be balanced against the danger of copper injury in deciding whether to apply materials in individual orchards.

When honeybees are imported for pollinating the orchard and severe blossom blight results, it is suggested that, after a period of about two days, which is long enough to provide for adequate fruit set, the beehives can be placed out of flight range of the trees.

Post-blossom period

Spring jobs

Eradicate early spur and shoot blight following bloom before large cankers develop.

Break out all blighted spurs, shoots, and twigs of highly susceptible trees. After using a pruning tool, disinfect the wounds.

Use chemicals when there are many small cankers in highly susceptible trees. Apply paints to the canker surface and to several inches of the surrounding bark, as well as to the blighted spur or any other infection court through which the organism entered.

Summer jobs

Remove from the roots, trunk, and scaffold branches of susceptible trees all suckers or water sprouts while small and succulent and before they become infected. This practice not only discourages but eliminates many of the sucking insects, such as aphids, which frequent them.

Continue to break out early shoot infections in the more susceptible trees.

Retreat with chemicals the occasional cankers that were not controlled by the spring application.

Control the large cankers by: (1) Cutting back the cankered branches from one to two feet from the visible canker margin, disinfecting the tool, disinfecting the wound, and applying a wound dressing. (2) The scraping method. (This requires extreme care and is not adapted to active cankers unless in the hands of an experienced operator.) (3) Painting the canker and several inches of the diseased area with a chemical solution. (This is a rapid method which seems to have a place here where the problem is to save the affected limb.)

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